

There are 30 billion
records in the world today.
Someone finally figured
out how to play them.

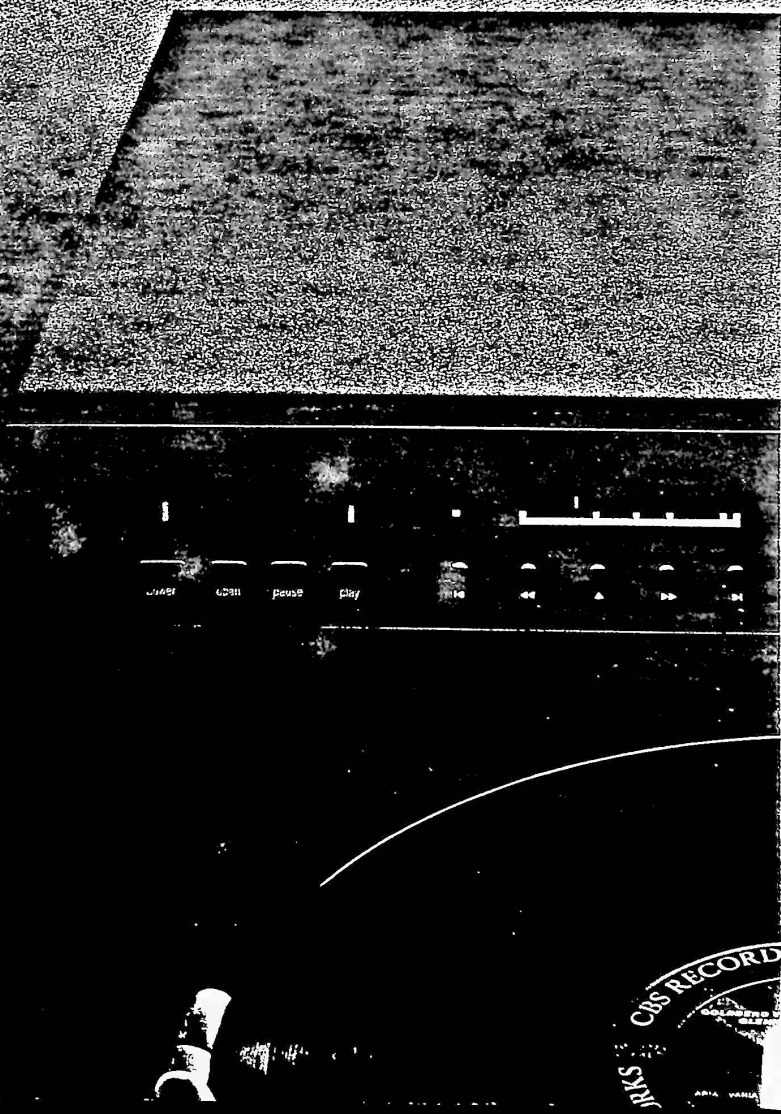


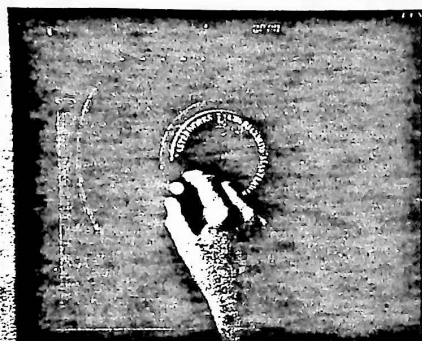
Introducing the world's first Laser Turntable.[™] Hearing is believing.

There is more musical information stored inside the narrow grooves of the far-from-obsolete vinyl record than most people ever suspect. The trick is getting it out. Most designers and manufacturers have pursued evolutionary changes in the tried and true turntable-tonearm-cartridge system. Final Technology, however, took a new approach. And after years of research, it works.

Imagine a laser beam shooting across a 50 micron gap, illuminating

the walls of each record groove, while sensors capture the reflections and the system translates the optical imprint into an accurate acoustic signal. Imagine a computer controlled laser assembly tracking each movement and constantly maintaining a position accuracy equal to 1/30th the thickness of a human hair between laser optics and record. Imagine a turntable that eliminates the inertial drag of tonearm and cartridge, without a hint of rumble. This is not the substance of fantasy, but the state-of-the-art in record playback systems. The Laser Turntable. Nothing





Keep the record surface and LTI system dust free with the Laser turntable's 360 Record Cleaner which comes with each Laser turntable system.

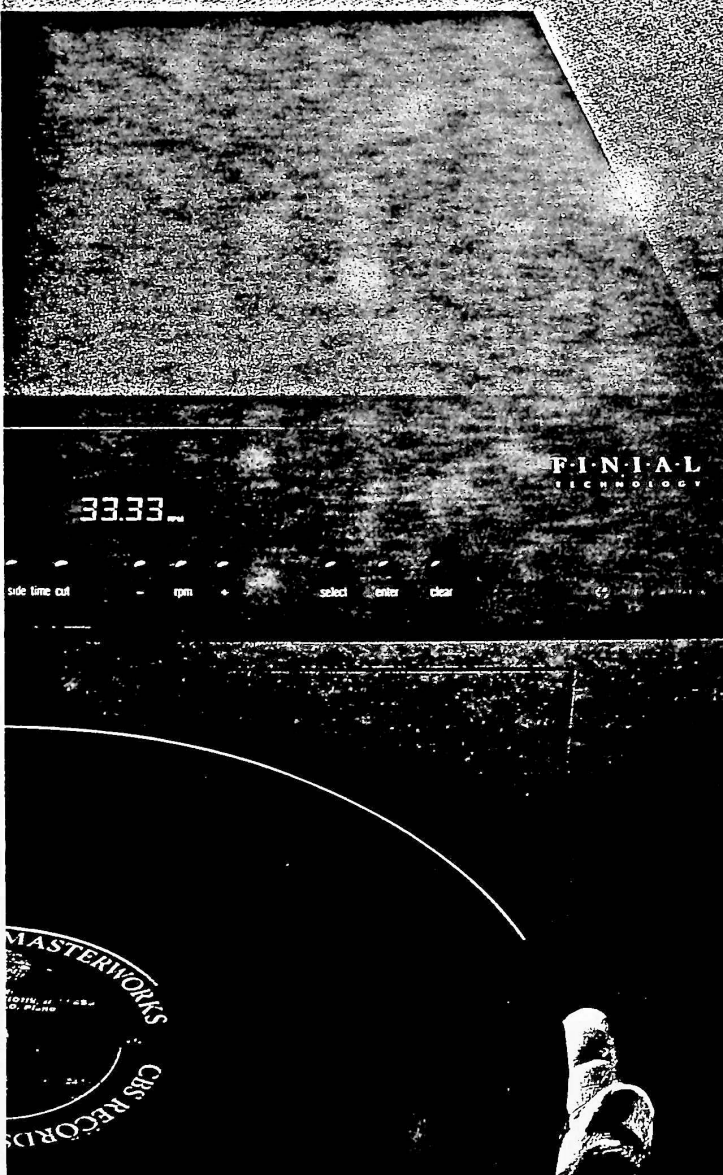
touches the record. No scratching. No grinding. No contact. No wear. No compensating for the idiosyncra-

sies of form and materials in matching the tonearm and cartridge design. The penetrating laser beam "reads" the grooves in an unbiased manner.

New records stay new. Old records sound revitalized because the laser beam reads more than just the worn contact points of previous styli. No grunge on stylus. No stylus! Just pure transparent sound. This technical tour-de-force is even more amazing when you consider that there is nothing digital about it. The laser and all subsequent audio circuitry are analog

and so retain all the special sound still found only in records.

No matter what you may have heard in the past, no matter how much you're prepared to spend for a record playback system, you must hear the Laser Turntable. It is, quite simply, the finest record playback system in the world.



A brief explanation of how to operate the Laser Turntable™, and how it works.

FINAL
TECHNOLOGY

The ergonomically designed front panel offers convenience, programmability and control of all record playing functions, while providing an unprecedented set of informational displays.

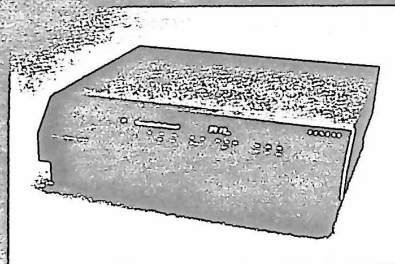
While the technology applied in the Laser Turntable is leading-edge from both the computer and applied optics industries, the operation is astonishingly simple. Touch POWER, then touch OPEN. The drawer slides out. Place the record inside, touch PLAY and the drawer closes automatically. After storing the song boundaries and groove locations in its memory by scanning the record surface, the sensor moves to the first song and begins playing.

One display provides you with a visual representation of the memorized record surface, while the other display indicates elapsed, remaining or total time for each cut or the whole side. A soft-touch control panel permits forward or backward scanning, cueing to cuts and complete programming. A calibrated speed control is variable from 30 to 50 RPM. It's that easy. No tedious set-up. No temperamental table and tonearm.

However, to make things that easy is not easy. Underneath the sleek exterior is a complex network involving the integration of three major component assemblies: the turntable, the tracking mechanism and the laser optical assembly.

The turntable system uses a microcomputer to control speed, to keep track of time, to memorize song

boundaries, and to track the record. The platter is not heavy and massive because it does not need to overcome the resistance of a stylus dragging across the record surface, or to employ inertia as a speed control mechanism.



A technological breakthrough is housed in this triumph of design.

The laser optical assembly serves, in effect, as the tonearm. The beams of light are directed into the record groove and reflected back to the sensors. This controls both the tracking and the gap between optics and records, and most importantly, reads the information along the walls of the record groove; conventional styli achieve contact with only a fraction of the information-bearing record surfaces. The laser typically scans more than forty times that amount of groove wall area—surfaces previously untouched by a typical stylus. More information is read, more music is played.

To further increase the pleasure of the music, a proprietary Noise Blanker circuit helps eliminate ticks and pops. The Noise Blanker differentiates between valid musical signals which have reverberations, and ticks and pops which do not. The circuit acts remarkably fast—within 1/1000th of a second—and causes no audible effect on the musical signal. It can be switched on or off at will. Less noise, more enjoyment.

Final Technology introduces the Laser Turntable. Better sound at the speed of light.

Specifications

Weight: 40.5 lbs
Height: 6 1/4 inches
Width: 18 3/4 inches
Depth: 18 3/8 inches
Speeds: 30 to 50 RPM in 0.1 RPM steps
Temperature Operating Range: 4°-44° C, Thermal cut-off @ 44° C
Line Voltage: (U.S.) 117V, 60 Hz
Record Type: 12" black vinyl LP 33 1/3 RPM records, 12" black vinyl EP 45 RPM records
Output: R.I.A.A. equalized, line level output

F · I · N · I · A · L
T E C H N O L O G Y

707 E. Evelyn Ave., Sunnyvale, CA 94086 (408) 720-9800



A Laser Turntable for vinyl records, finally a reality!!

Dear Music Enthusiast,

Yes, it is a reality, a turntable that uses *laser beams* to read normal 33 1/3 r.p.m. records, or 12" 45 r.p.m. records.

The greatest advantage for the professional user is to know that the sizeable investment that has been made throughout the years in vinyl records can now be *preserved indefinitely*. Because the *Finial turntable* uses *laser beams* to read the information that is stored on the record groove wall *no wear or damage* is inflicted on the irreplaceable music stored there. As you are aware the continual playing of a record with a normal turntable stylus exerts 20,000 pounds per square inch on the vinyl surface. So, every time a record is played wear occurs and additional unwanted materials can be ground into the record groove rendering it unplayable.

The Finial Laser Turntable alleviates this problem and has many advantages over a conventional turntable as you see outlined below.

ADVANTAGES:

1. Elimination of record wear — due to lack of physical contact
2. Better frequency response — no resonance like any stylus will have
3. Absence of rumble — no contact with the record groove wall
4. No acoustic feedback — same as above
5. No crosstalk — L & R channels independent, not connected like normal stylus
6. Most *old worn records* can be played because the laser beam rides higher in the groove wall than where a typical stylus rides.
7. Scratched records can be played because scratches are typically across the top of the grooves, the laser beam reads further down the side of the groove.

FEATURES:

1. Fast Forward just like a compact disc player, in increments or by tracks
2. Cueing to allow precise start up of the record
3. Tick and pop noise reduction to reduce irritating non-musical noise
4. Total, remaining, and elapsed time readout for each cut and for the total record side.

5. R.P.M. adjustable from 30-50 r.p.m. in increments of (.1)
6. You can program songs that you wish to play in any sequence.
7. Microcomputer will flash up to 7 error messages to indicate when a problem is present.

Since 1929 there have been six patented optical turntables which have attempted to reproduce the signal present on the side of a record groove wall, but they did not succeed.

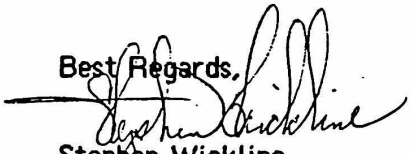
Even with the advent of the compact disc player our task was not made easier. All compact discs are made to a rigid standard and if they deviate from that they simply will not play on today's CD players. In contrast, the record industry has had loose standards and the development of a laser turntable that could read every record with the wide variations in cutting standards has been very complex to master, but

After eight long, grueling years of research and development, the *one and only* Finial Laser Turntable is finally being sold to the public in very limited quantities. This is due to the complexity of the assembly process, especially the optics portion of this turntable. Consequently, the cost of this revolutionary pioneering research which has taken almost a decade, and the laborious hand assembly, which limits the quantity of production of this product, dictates that the Finial Turntable must have a very high retail price\$26,000. Leasing is also available at approximately \$800 per month.

As a music lover with a library of records which could number up to 10,000 or more, you can *preserve your investment indefinitely* for a cost of a little more than *two dollars per record*. Also, due to the fact that each laser for each channel reads a surface which is (20)twenty times greater than a normal stylus you get more of the signal and *the best quality sound* possible from your vinyl records.

If you are interested in this product please write or phone the number listed on the bottom of the cover page and I will be happy to answer any questions you may have, or arrange for a demonstration of this amazing laser turntable.

Best Regards,



Stephen Wickline
Manager of Special Markets

F·I·N·I·A·L
T E C H N O L O G Y

February 1989

Dear Enthusiast,

Some time ago you sent to us this self-addressed stamped envelope for the purpose of receiving information on the Laser Turntable. Recently, we have changed our plans and we will not be introducing the Laser Turntable.

This decision was especially difficult due to the fact that we had commenced production and we were on the verge of shipping our first units for sale during the last week of December.

The reasons for the decision are economic, and are covered in the attached press release. Thus, at this point, Finial Technology will cease operations except to support the licensing of the technology, as possibly some other company will introduce the product under license from us. Subsequently, the company decided that none of the production units would be sold.

Enclosed you will find a copy of our press release and a flyer with questions and answers as a souvenir of what might have been.

CONTACT: Fran Dym

News

FOR: Finial Technology
707 East Evelyn Avenue
Sunnyvale, CA 94086

RELEASE: IMMEDIATE

MARKETING OF THE LASER TURNTABLE CANCELLED BY FINIAL TECHNOLOGY
COMPANY WOULD CONSIDER LICENSING THE TECHNOLOGY OR JOINT VENTURE

Finial Technology will not market the Laser Turntable™, which was planned for introduction in January 1989. The company, however, would consider licensing the technology or the possibility of a joint venture. The decision was explained to reporters attending the Winter 1989 Consumer Electronics Show by Jacques Robinson, Chairman of Finial's parent company, Carillon Technology, at a press conference on January 6th, where initial production models were displayed and demonstrated.

"We completed the initial production run and concluded that the unit is too expensive to produce," Mr. Robinson said. "It was not until the production run was completed at the end of December, that we were able to actually cost out the unit and realized that the turntable would have to carry a retail price between \$8,000 to \$10,000."

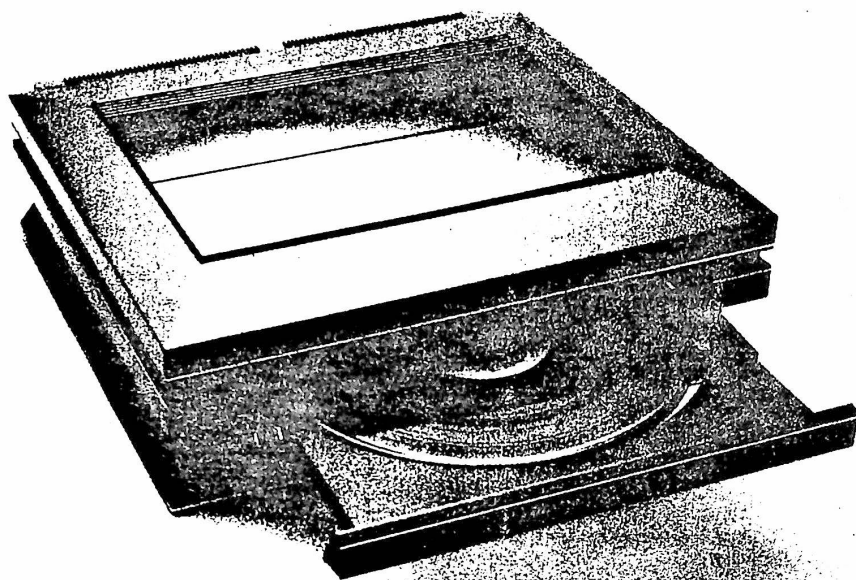
"There is a market for the turntable at that price," Mr. Robinson continued, "but the goal of Carillon Technology is

- more -

larger scale production of mid to high-priced components, not limited production of esoteric products. We are amenable to licensing the technology or would consider a joint venture with a suitable company."

The demonstration of the Laser Turntable included an A/B comparison of recordings on both LP records and compact discs, and a subsequent technical session. "Finial Technology has now demonstrated the efficacy of the technology and shown the industry that it is reproducible," Mr. Robinson concluded. "We have brought it to life. It is now up to someone else to bring it to the market."

#



THE Laser Turntable

RAY OF HOPE FOR THE LP?

by Philip De Lancie

The laser is certainly among the most powerful and versatile technological tools to emerge this century. In the prerecorded music industry, lasers have made possible the success of digital audio at the consumer level in the form of the compact disc. Through their use in thermal magnetic duplication (see last month's *AfterMix*), lasers may also soon be playing an important role in software production for rotary head digital audio tape (R-DAT). And in the realm of analog audio, a small firm in Sunnyvale, California has been working on applying laser technology to a prerecorded music format that has achieved software distribution perhaps 1,000 times greater to date than that of the CD. The firm is Finial

Technology, the format is the vinyl LP and the product is the Laser Turntable.

As the name implies, the Laser Turntable is a record player in which optics replace mechanics as a means of extracting information from the groove. Gone are the stylus, cartridge and tone arm of conventional turntable designs. In their place (according to Finial's literature) are solid state laser diodes guided by "a combination of closed loop servo-tracking and micro-positioning systems." The location of the groove is optically sensed by a "high speed digital micro controller chip," which regulates the movement of the light beams. Beams are reflected from the groove, read and converted into program signal. The player's platter is belt driven by a computer disk drive microstepping motor, which is said to enable extremely precise con-

trol of positioning and velocity.

Finial Technology claims many important advantages for their system over standard turntables. The elimination of physical contact between player and disc is obviously a big plus in terms of record longevity. Worn records reputedly sound better because the beams are able to pick up program from the least worn areas of the groove wall. The system is also claimed to be less susceptible to ticking and popping, immune to skipping and able to leap tall warps in a single bound (thanks to its height servo system). Records in perfect condition are supposed to sound better as well, with improved frequency response and reduced distortion. The player also offers such convenience features as full programmability and front loading.

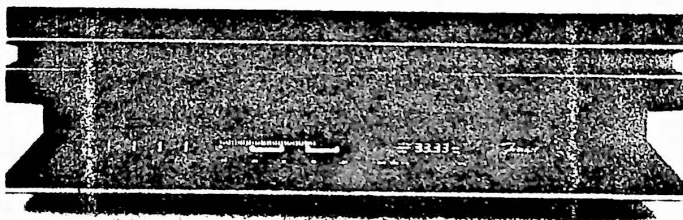
With all these attributes, and only

one obvious flaw (the suggested list price of \$2,500), the Laser Turntable looks intriguing on paper. To get beyond the general description found in Finial's press packet, I contacted the company and spoke with Michael May, marketing manager. Unfortunately, much of the technology developed by Finial for the player is "patent pending," meaning that the company is very reluctant to reveal much in the way of details on how their system actually functions. After attempting to clarify a few technical points within

groove of interest and staying at the proper distance. The height servo system is just keeping that distance very accurate between the groove and the sensor. So the systems are tied together, but it's a subsystem, a different servo, which is actually doing the height servoing, moving the laser up and down.

Mix: Is the information upon which the adjustments in height are based coming from the same two beams which read the program?

Finial Technology Laser Turntable front view



this restriction, May and I moved on to discuss Finial's plans for the product, as well as the effect, if any, of the industry's current format trends on his company's goals.

Mix: Explain as much as you are able to about how the beams work to pick up program from the groove.

May: The system has two beams, one for each channel. Those are the only beams used, both for extracting the music and for tracking. These come from basically the same laser diodes that CDs are using. Of course, it's a different optics head or optics package than the CD because we're talking analog.

The light reflects back from the groove to the sensors which convert the signal into music. [Changes in the reflection are converted into changes in voltage.] The actual characteristics of the reflections is where our formula is. We tried 13 or 14 different techniques before we hit the one that worked well, although there were others that worked moderately well. There are a lot of different ways to approach it in terms of how you aim the lasers, what kind of characteristics you use, what you look for and what you look at.

Mix: What is the relationship between the height servo system [which allows playing warped records, within limits] and the extraction and tracking systems?

May: The systems are all tied together because it's all part of staying over the

May: Yes. There is no feeler. All you have is those reflections, which are the player's interface with the record.

Mix: How does the system distinguish between height variations that are part of the program (groove depth changes) and those that result from warping?

May: I would have to tell you how we read the groove in order to explain that. You have to be careful about making assumptions about how the groove is read. There is no problem as far as getting confused between music content and height.

Mix: Explain the claim that this player gives better frequency response than conventional turntables.

May: There are none of the mechanical resonances that you have to deal with in a stylus. Any time you have a mechanical element, it's going to resonate. Better styli resonate less than others, but they are still mechanical. They have the contact against the record, dragging along at high pressure. When you pull that out of the equation, and you have no resonances, then you can have a truly flat frequency response. You can choose the shape and size of the laser footprint you use so that you have flat frequency response out to 20kHz.

Mix: Has the player demonstrated the ability to track passages, especially at inner diameters, which are difficult for conventional turntables to track without edginess and distortion?

May: Yes. Of course, there are limits. We're not really addressing ourselves to things which are completely out of the norm. We're looking at everyday playing: improving things at the inner diameters, tracking more accurately. Those are the areas where we really will shine. The response to transients is phenomenal because you don't have the inertia of the tone arm. You still have servos that have to start and stop, but those are much faster.

Mix: Do you foresee any professional applications, aside from radio stations and dance clubs, for the new system?

May: Yes. Getting smart about how records are cut and made was a key part of understanding what we needed to do. So, from very early on we tapped various industry professionals, including Fred Catero [recording engineer; owner of Catero Records]. And one day Fred said, "It really would be wonderful if I didn't have to send my lacquer masters off to get test pressings just to find out if they are all right. It would save me time and money if I had a player that I could use to play the lacquers." It would have to be able to take a 14-inch disc, but there is really no reason we couldn't do that. It's a small market, and we would have to assess whether it makes sense from a business perspective, but technically, we've developed the technology and we can make variations on it.

Mix: Assuming that the Laser Turntable has superior tracking ability, some of the tracking problems for conventional players that you would be listening for might not show up when listening to the lacquer by laser.

May: That is something we would have to consider. Maybe you wouldn't get a useful representation, assuming that everybody is still using conventional turntables.

Mix: Is it likely that these units could ever be manufactured in models that could sell at a price, say under \$400, that would allow everybody to have a laser turntable?

May: It's really a matter of economies of scale, volume and time. The beauty of the system is that it isn't so complicated that it's always going to cost \$2,500. It's similar in complexity to a video laser disc player. It's the same kind of thing: a sort of disc drive tracking system and laser reading systems. You have the same kind of stresses and the same kind of parts and development that goes into that. So Pioneer or somebody like that could take this thing with their existing factory and, with the right kind of development, get the price down there. I think you will see that happen. There are no

inherent technological obstacles to having a model for the mainstream consumer.

Mix: What would be your guess as to how soon we might be seeing something like that?

May: It depends on many different things. It's technically feasible at any time. But it's a function of who gets involved, how many are sold, whether people are licensing the technology and what the reaction is to the product. You're probably not going to see one that cheap for at least two years, and it could be longer than that. The typical evolution of that process is probably represented by CD players and VCRs—five or six years.

Mix: Your immediate plans call for manufacturing in your own facility here in the U.S. Is that just an initial phase to prove the feasibility of the system, after which you may license the technology to some manufacturer or group of manufacturers for mass production?

May: Our strength is innovation. I think that will continue to be our strength. We are certainly set up and capable here for manufacturing in low or moderate volume. Over time, we could grow and become a higher volume manufacturer, but realistically our position is that we're good in innovation and in the high end, and we want to maintain that. There are a number of companies, Japanese and others, that have expressed interest in either licensing or joint partner relationships. There are certainly a lot of different routes that we can go as far as the laser turntable becoming more of a high volume, mass market product. As far as exactly what strategy, which company and how soon, that's all still dynamic.

Mix: Regarding the models to be manufactured by Finial itself, who do you see as the market for a turntable that costs \$2,500?

May: Different people have their various vices. There are a fairly sizeable number of audiophiles that currently buy \$2,500 turntables. Those are our initial customers. I think there are also a fair number of people who typically have not perceived a difference between a \$400 and a \$2,400 turntable. But, what our \$2,500 turntable offers them that they don't get from another, besides superb sound, is that it doesn't wear out their precious record collection. So our market will be audiophiles, music lovers and record collectors.

Mix: When will your first production models be available in stores?

May: We're looking at slowly rolling

things out towards the end of the year. We've shown prototypes, but there are certain aspects of software and front panel controls that have to be completed before we're ready. We'll start production when we finish up some of those final developments. We won't release the product until it's right.

Mix: What are your thoughts on how the player fits into the overall context of the current struggles in the music industry between competing product distribution formats, such as cassettes, LPs and CDs?

May: The important factor for us is that there are billions of records out there already in people's collections, and they are still buying around 200 million yearly. Maybe that goes down some, but there is still a need for a no contact system of playing those records. It's both for the records people are still buying and the ones they have had around and consider part of their history from the '60s and '70s. That's important. There really does seem to be a need that we can fill with this product. It's not just a super technology that's past it's time.

Notes

The Dub Centre, Inc. of Owings Mills, Maryland has expanded its video and audio duplication facility. Vid-

eo decks now on-line at the plant include four one-inch (Ampex and Sony), nine 2-inch Quad (RCA), 70 3/4-inch (Sony) and 260 half-inch (200 Panasonic VHS; 60 Beta). An audio expansion is in process as well, which will allow the company to offer both high volume cassette and reel-to-reel high speed duplication. The Dub Centre also plans to include free pickup of masters from anywhere in the country and 24 to 48 hour turnaround in its client services.

Larry Rallo, audio/video marketing manager for BASF Corporation Information Systems has announced the introduction of BASF 8mm video cassettes in 30, 60, 90 and 120 minute lengths. "While we don't see this developing as a major market," Rallo said, "we will continue to offer our retailers a complete range of choices of video and audio cassettes."

Ampex Magnetic Tape Division has prepared a brief news release designed to aid duplicators in selecting appropriate tape stocks for their audio duplication projects. Information is available through Bob Griffin at (212) 255-8491, or from Jerry Campbell, audio product manager, at (415) 367-3888.

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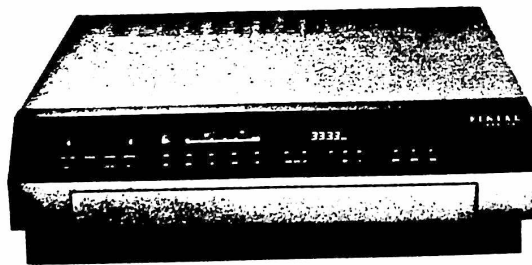


The most often
asked questions about the
new Laser Turntable™
from Finial Technology.

- 1 **Q. How does the Laser Turntable™ work?**
A. Laser beams are bounced off the groove walls, with reflected light captured by a set of precisely positioned sensors and are converted to music. These reflections are also used to control the servo-positioning (tracking) system.
- 2 **Q. How does the Laser Turntable differ from conventional turntables?**
A. 1. The LT-1 has superior sound quality because there are none of the distortions caused by the contact between stylus and groove as in all conventional turntable systems. 2. The LT-1 never wears records down; the conventional turntable erodes the record grooves with every playing (over 20,000 pounds per square inch of pressure on the vinyl). 3. LT's laser optics look at a different part of the groove and thus avoid much of the worn or destroyed area. 4. The LT's lasers are rated at 10,000 hours and thus should provide many more hours of listening than a conventional stylus. Service, if it is ever required, can be done by an authorized Finial service center.
- 3 **Q. What are the benefits of a Laser Turntable?**
A. The primary benefits are improved sound quality, no wear of records, revitalization of old records and no stylus replacement.
- 4 **Q. Does the Laser Turntable require the use of a conventional turntable?**
A. The Laser Turntable replaces the complete turntable system of table, platter, tonearm and cartridge.
- 5 **Q. Can a conventional turntable and tonearm be converted to a Finial Technology Laser Turntable by using laser pick-up?**
A. The sophisticated platter drive and servo-tracking system are integral parts of the Laser Turntable and superior sound quality it produces. Thus your tonearm cannot simply be replaced by a laser pick-up.
- 6 **Q. What are the differences between the Laser Turntable and a CD player?**
A. The LT plays your existing library of 12" records, both 45 and 33 $\frac{1}{3}$ RPM. The Compact Disc player plays "CDs," special digital audio discs. The LT reads analog information, the CD reads digital information.
- 7 **Q. Will this unit play CD's or Laser Discs?**
A. The Laser Turntable is dedicated exclusively to optimize the playback of LP vinyl records.

- 8 **Q.** **Is the Laser Turntable digital?**
 A. No. Because record grooves are analog, the purest music is maintained by keeping the signal analog throughout the system. There is no need for digital conversion.
- 9 **Q.** **Is there any contact with the record?**
 A. There is no contact at all between the laser pick-up and your record. Reading and tracking are accomplished solely by laser. No contact, no wear.TM
- 10 **Q.** **How do you connect the Laser Turntable to a conventional stereo system?**
 A. The LT can be easily used with any stereo system. It has two gold-plated phono jacks which deliver 1 volt of RIAA equalized signal to an AUX input or high level input of your receiver or preamp. It should not be connected to a PHONO input.
- 11 **Q.** **How does dust affect system playing?**
 A. Smaller dust particles have little or no impact on the laser; larger pieces of dust or dirt block the light and can cause a momentary click. (Refer to Question #12.) Unlike the stylus, the laser does not grind the dust into the groove or accumulate it.
- 12 **Q.** **Is record cleaning important when using the Laser Turntable?**
 A. Each LT-1 is supplied with an in-the-drawer cleaning system called the 360 record cleaner. We suggest you use this and the 360 cleaning fluid before each play in order to keep the optical system dirt-free, as well as reduce noise during playback.
- 13 **Q.** **How do scratches affect the system?**
 A. Small scratches have little or no affect on the system; large scratches are picked up as a momentary click. The system should play through most damaged or scratched vinyl.
- 14 **Q.** **Are the pops and ticks associated with dirt and scratches audible through the Laser Turntable?**
 A. The Laser Turntable is equipped with a proprietary "noise blanking" circuit. This "Noise Blanker" can differentiate between ticks caused by dirt or scratches and musical information, which has reverberation. This circuit then rapidly acts to remove the noise without destroying the musical signals. Some ticks and pops are still audible, especially if there are many of them, close together.

- 15 **Q.** *How are worn records played by the Laser Turntable?*
A. *The stylus wears down and pits only a small portion of the groove—leaving much of the groove untouched for the laser to read cleanly.*
- 16 **Q.** *How does the Laser Turntable deal with warped records?*
A. *The Laser Turntable has a sophisticated “height servo system” which keeps the distance between the optics and the record constant. Warps or thickness variations in the records are “tracked out” so there is no influence of warps on the music. However, the system may not play very badly warped records.*
- 17 **Q.** *Is there need for special cleaning for the laser lenses of the LT-1?*
A. *The Laser Turntable should require similar or less cleaning than a high quality CD player, done periodically by a qualified professional service technician.*
- 18 **Q.** *What happens if your Laser Turntable is vibrated or jolted?*
A. *Acoustic vibrations and normal physical vibrations in the area of the Laser Turntable will not normally interfere with operation. A violent bump might cause a wow or momentary skip.*
- 19 **Q.** *Is the Laser Turntable simply the best device for playing an inferior medium?*
A. *The vinyl record has tremendous sound quality potential which cannot be fully tapped by the mechanical stylus; the laser is able to maximize this sound quality. Many “golden ears” maintain that analog vinyl records are superior to CD’s. A 1 KHz square wave appears smoother when vinyl is played by the LT as opposed to the signal shown by a CD. New pressing technology is making vinyl records even better.*



F · I · N · I · A · L

T E C H N O L O G Y

707 East Evelyn Avenue Sunnyvale, CA 94086 (408) 720-9800

The Optical Turntable, Finally a Reality

Robert E. Stoddard
Robert N. Stark

Finial Technology, Inc., Sunnyvale, CA 94086 USA

Presented at the 85th Audio Engineering Society Convention in
Los Angeles, California. November 4, 1988.

The Optical Turntable, Finally a Reality

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A non-contact system using lasers, and a transducer head that hovers a fixed distance above the rotating record, can track and play vinyl records. Unlike earlier attempts to use light to play records, this system produces the music with "audiophile" quality. A description of record characteristics and the history of optical turntables is presented.

0 INTRODUCTION

It has long been a dream of audiophiles to extract a record's information without the physical contact with the groove that can result in wear and ultimately distortion. This dream is now realized through the use of servo-controlled actuators containing optics. These actuators require no physical contact with the record and can be used to perform the basic functions of a conventional mechanical stylus. Warps and record thickness variations are overcome through the actuator's vertical tracking capability. Precise lateral tracking is performed even during extreme modulation, record runout and song leadovers. In addition, the record's audio is extracted with the required submicron resolution.

1 CHARACTERISTICS OF RECORDS

Stereo audio signals are encoded in the velocity of the two orthogonal groove walls cut into a rotating vinyl disk or record. These two walls form a "V" groove in the record, each forming an angle of approximately 45 degrees with the land's horizontal plane. The top edge of each wall is called the land-groove interface, as shown in figure 1.

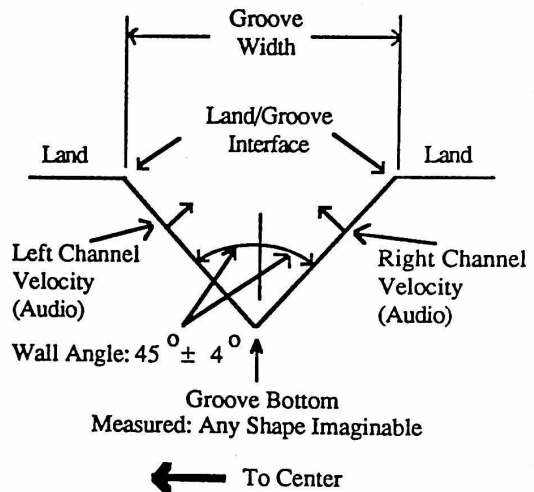


Figure 1: Record Groove Cross Sectional Geometry

The modulation angle is the angle the groove wall makes with respect to the tangential velocity vector due to the rotating record. As shown in figure 2, this angle is related to the desired audio signal by:

$$\text{Wall angle} = \tan^{-1} (V_s/V_t)$$

where:

$$V_s = \text{normal velocity vector (audio)}$$
$$V_t = \text{tangential velocity vector}$$
$$= 2 \pi R / 1.8 \text{ sec}$$
$$R = \text{groove radius}$$

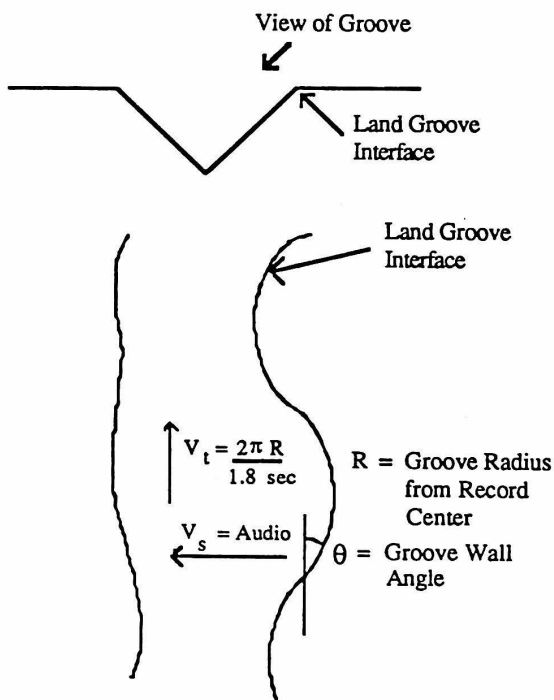


Figure 2: Audio Signal Encoded in Groove Wall Angle

Some record parameters measured include:

Groove width	0 to 150 μm
Groove excursion	0 to 150 μm
Land width	0 to 300 μm
Groove pitch	50 to 300 $\mu\text{m}/\text{groove}$
Wall angles	41 to 49 degrees
Modulation angles	-45 to 120 degrees
Land angles from horizontal (warp)	-2 to 10 degrees

Wide ranges experienced in the table above provide challenges to conventional stylus playback of records and cause even more problems when attempting playback with a non-contact optical system.

In addition to problems of the above parameter ranges, mechanical defects occur in a high percentage of records. These can result from cutting stylus modulation levels higher than those for which the stylus was designed. They can also result from carelessness in the cutting and mastering process.

Occasionally grooves are cut with insufficient groove spacing, and land width goes to zero as two adjacent grooves momentarily merge. Variable pitch and groove width can result in variable groove density. For example, in one revolution there may only be one 150 μm groove in a 200 μm region, while in the next revolution, there may be over three 50 μm grooves in a 200 μm region.

Also, record material removed from the groove deposited on the land-groove interface results in protrusions or "horns" on the interface. Horns are not created during mastering if the cutting stylus is sharp, and shaped and heated properly, to allow material removed from the groove (the chip) to roll out in one fine string of material. In some mastering processes, horns are created and then broken off in an intermediate mastering step.

Any system designed to play a record optically must use one or more of the three physical regions containing audio information. These three regions: the land-groove interface, groove wall, and groove bottom, are shown in figure 3. Audio, encoded in the velocity signal, can be determined from measuring the trajectory of each land-groove interface. Unfortunately, the land-groove interface is a position signal requiring a noisy derivative process to generate the velocity signal. Also, this interface is often corrupted by horns, pits, and surface scratches. The land-groove interface is, therefore, low-fidelity information.

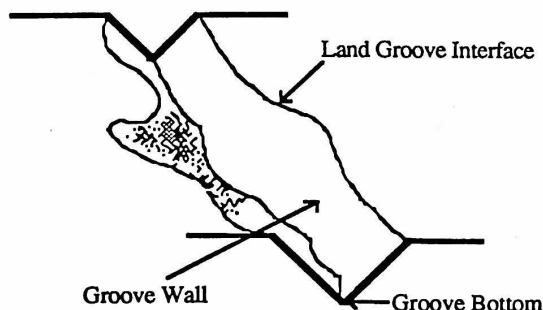


Figure 3: Data Extraction Problems

Stereo audio can also be determined from the lateral and vertical trajectory of the groove bottom. The groove bottom, however, is not a

well defined region. Every pressing has a different shape and the groove bottom tends to collect dirt. Finally, the groove bottom trajectory is a position signal, requiring a derivative circuit, like the land-groove interface signal.

The best surface for detecting the audio signal from a record is the groove wall. The technique used to measure groove wall physical displacement also requires a derivative circuit creating a noisy signal. However, it does not have the additional problems found in the groove bottom and the land-groove interface. The system described in this paper is the first documented system to measure groove wall velocity optically to create stereo audio signals.

2 HISTORY OF OPTICAL TURNTABLES

Each of the six previously patented optical turntable techniques has one or more fundamental flaws that prevent it from producing a quality audio signal. Most of these techniques produce a signal proportional to the position, instead of the velocity, of the groove wall. They are as follows:

Friebus(1), 1929: This system uses a simple microscope to image the groove wall onto a photocell. This image varies in intensity as the light density on the groove wall varies with wall angle and position. The resulting signal is noisy due to reflection coefficient variations of the vinyl, as well as the differentiation process required to recover audio. This system would have great difficulty with modern variable pitch, narrow groove, high frequency, stereo records.

Dahlen(2), 1969 and Lehman(3), 1983: Land-groove interface regions are imaged onto left and right photocells. Physical motion of the wall causes the amount of light collected by the photocell to vary; large excursions of the wall from the groove center reflect less light off the land than small excursions. This system has several fundamental flaws. First, recorded audio is sensitive to the erratic reflection coefficient of vinyl. Second, recorded audio is sensitive to land-groove interface problems, such as horns and pits. Third, the system can not handle large lateral

groove excursions; a 75 μ m groove can move 125 μ m laterally and the signal can thus be lost. Fourth, variable pitch and groove widths can cause the system to play more than one groove at a time. Finally, this system detects the wall position rather than the velocity.

Mori(4), 1975: Reflected laser beam intensity disturbances caused by the groove wall shape are detected by this system. Light rays from different portions of the groove wall interfere with themselves on the photocell detector and the detected intensity variations are processed into the audio signal. This system is sensitive to the erratic vinyl reflection coefficient and the audio signal is proportional to the groove wall position rather than the desired velocity signal. Finally, this system is inherently non-linear; difficult analog signal processing electronics are necessary to linearize the output.

Tanaka(5), 1979: This system reflects a laser beam off the groove wall, through imaging lenses, and then onto a charge coupled device (CCD) segmented image sensor. The beam on the CCD sensor is interfered with a reference laser beam to form an interference pattern. The fringes of the interference pattern move as the groove wall position changes. As with Mori's system, Tanaka's system requires difficult analog signal processing and is sensitive to wall position, but not velocity. The wall angle range of the system is severely limited to about 12 degrees by any practical lens used to collect the reflected beam; this is about one third the minimum required detection range for reproduction of quality audio.

Iwasaki(6), 1980: In this system, a small top-mounted light spot is scanned across the groove and the land on both sides of the groove. The reflections are then detected by a photocell. Land reflects about 30 times the light reflected from a groove. Locations of land/groove interfaces are derived from the time the detected reflected intensity signal goes from high to low and low to high. This system, like the others, detects the groove wall position not the desired wall velocity, and produces audio signals corrupted by problems such as horns and pits at the land-groove

interfaces. Implementation would be very expensive since it requires the light spot to move about 250 μ m at a scan frequency of over 40kHz. Because practical scanners are limited in bandwidth, the light spot moves across the groove with a sinusoidal trajectory instead of a triangular motion, adding non-linearities to the audio.

Heine(7), 1981: Heine's system over-illuminates the groove with a large laser beam and converts the motions of the reflected diffraction rings into the audio signal. Again, this system is sensitive to position, not velocity and limited to about 2kHz signal bandwidth due to the large light spot required. Furthermore, it can not play modern records with their variable pitch and groove widths. In fine pitch narrow groove regions, two or more grooves would be played.

Many individuals and companies have attempted to create an optical turntable. However their efforts have, until now, been unsuccessful.

3 TECHNICAL DESCRIPTION

The laser turntable described in this paper is a complete system that overcomes the problems that caused other optical turntables to fail. This system contains 1) an optical head that performs the lateral and vertical tracking functions, and extracts audio, 2) a carriage that moves the optics from the beginning of the record to the terminal groove, 3) a turntable that rotates the record, 4) audio and servo electronics, and 5) a microcomputer that controls the system.

The laser turntable's basic building block is a silicon optical sensor that can detect the position of the light beam on the sensor. This sensor, called a Position Sensitive Detector (PSD), is a photocell with a resistive back plane leading to two electrical output terminals. Each ray of light hitting the PSD creates an electrical current proportional to the intensity of that ray. The current goes through the back plane resistance to each output terminal. If the light ray hits at one end of the PSD, all the current leaves the terminal at that end; with no output at the

other end. When the light ray hits the center of the PSD, the two outputs are equal. The sum of the two currents is proportional to the total light intensity collected by the PSD. The difference between the two outputs is proportional to the position of the light hitting the PSD. This difference value varies linearly with the total light intensity collected. By dividing the difference by the sum, a position signal is generated that is independent of the amount of light collected by the PSD. The position output represents the center of intensity of all rays in the spot hitting the PSD, independent of the spot shape and intensity.

Circuitry performs the following mathematical operations:

$$I_1 = I_0(L/2+X)/L \quad I_2 = I_0(L/2-X)/L;$$

L = PSD active length

I_0 = total output current

X = light location on PSD, $X=0$ is PSD Center

$$V_1 = R I_1$$

$$V_2 = R I_2$$

R = load resistance

$$V_d = V_1 - V_2 = \frac{2I_0 X R}{L} \quad \text{difference signal}$$

$$V_s = V_1 + V_2 = I_0 R \quad \text{sum signal}$$

$$V_{div} = V_d / V_s = \frac{2X}{L} \quad \text{position signal}$$

3.1 Audio Detection System

The audio detection system accurately detects the velocity (audio) of each groove wall. This system has an independent set of optics to play each groove wall. Each channel has a light beam (left and right channel data beams) incident on the groove wall and a PSD to detect the reflected beam, as shown in figure 4. The PSD is 12mm long, located 3.5mm away from the groove wall. PSD position output, V_{div} , is proportional to the tangent of the reflected beam angle, which in turn is proportional to the angle of the groove wall. As was shown earlier, groove wall angle is proportional to wall velocity. The incident laser beam hits the

groove wall at an angle of approximately 58 degrees above the horizontal record plane and in the plane normal to the tangential velocity vector as shown in figure 4. The PSD divider output is:

$$V_{div} = K_1 h \tan(2 \tan^{-1}(V_s/V_t))$$

$$\approx K_2 \frac{V_s}{R}$$

R
h = wall to PSD distance
 $V_s \ll V_t$
 $K_1, K_2 = \text{constants}$

For signal velocities that are large compared to the tangential velocity, there are significant nonlinearities in the divider signal's relationship to wall velocity. From a linear expansion of V_{div} , a simple equation to linearize the measured velocity signal was developed:

$$V_{lin} = V_{div} - 0.037 V_{div}|V_{div}|$$

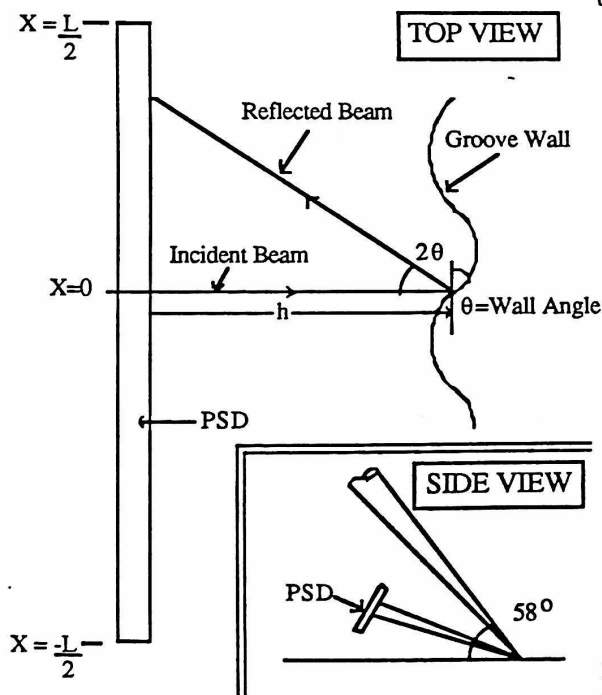


Figure 4: Data Extraction

Figure 5 shows the measured velocity output and its linearized output. The linearized divider signal is multiplied by the groove radius to create a signal, V_{sm} , proportional to the desired groove wall velocity, V_s .

$$V_{sm} = V_{lin} R$$

Groove radius is a slowly varying term that only controls signal level. The linearized velocity signal is equalized by the RIAA filter and attenuated to line level to produce output audio signals.

Our turntable's focussed laser beams on the groove wall are elliptical, with a Gaussian-like intensity profile across the beam that is described by the two dimensional Fourier transform of the collimated beams' intensity profile hitting the focussing lens. A Gaussian beam has a Gaussian focussed spot shape with the wide dimension of the beam focussing into the narrow dimension of the focussed spot. The size of a Gaussian beam (spot) is defined by where the intensity of the beam drops to

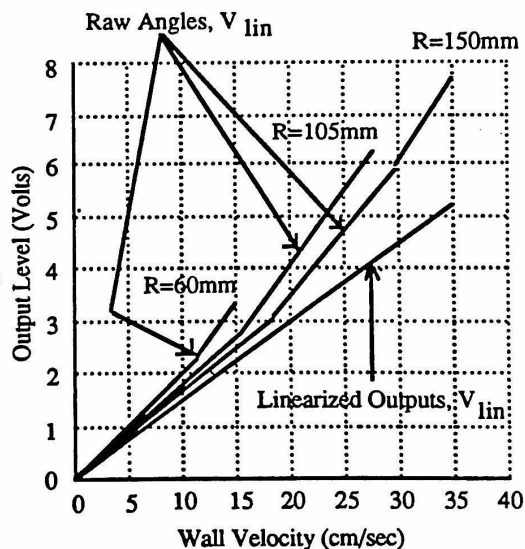


Figure 5: Output Level vs. Wall Velocity

$1/e^2$ (13.5%) of the peak intensity at the beam center. Approximately 95.6% of the beam intensity is within the $1/e^2$ width; 50% of the beam intensity is within the center third of the $1/e^2$ width.

Requirements for the audio extraction beam (data beam) spot size on the groove wall are simple. Intrack (direction of the tangential velocity vector), the beam needs to be small enough to detect the smallest audio wavelength in the record, and large enough so that the beam has enough depth of focus to stay in focus for all movements of the groove wall. Crosstrack (direction along a radial line), the beam needs to be small enough to easily fit in the narrowest groove, and large enough to integrate over as much wall area as possible.

The wavelength of the audio signal on the groove wall is:

$$\lambda = V_r/F = \frac{3.49R}{F}$$

where F = audio signal frequency.

A signal with a frequency of 20kHz has a wavelength of 25 μ m at the outer radius and 11 μ m at the inner radius. Our calculations and measurements indicate a flat response from DC to approximately 17kHz and approximately 1dB of attenuation for an inner radius 20kHz signal with our 1/e² spot size of 6 μ m. With the elliptical beam shape produced by the laser diodes, the elliptical focussed spot has an aspect ratio of approximately 3.3:1; creating a spot on the groove wall of approximately 6 μ m by 20 μ m. The 20 μ m crosstrack (up and down the groove wall) spot size easily fits in the narrowest sustained grooves found in records. When the groove gets narrower, during out of phase transients, the beam actually illuminates more than one groove. However, because the spot is focused only on the desired groove, the PSD only receives the portion of the beam that enters and leaves the groove on which the spot is focused. This causes a loss in intensity of the signal at the PSD, but due to the divider circuit that normalizes the PSD output by the overall received intensity, correct audio information is still detected by the limited portion of the beam collected. This beam will stay in focus for roughly 75 μ m along the beam axis; enough to play all groove modulations observed thus far.

Left and right channel optical systems are identical and symmetrical about the groove center. Both data beams are aligned intrack,

therefore there is no relative phase shift between the two channels. Since the two channels are detected by independent systems, there is no left/right channel crosstalk. Laser turntable crosstalk is always limited to crosstalk cut into the record.

Since this laser turntable is an angle sensor and not a velocity sensor, it does not suffer from the problems of a velocity sensor (e.g. a stylus and cartridge). It is insensitive to relative record/sensor motions. These relative motions show up in a conventional phonograph as rumble, acoustic feedback, warp induced wow, and tracking errors. Correct audio information is detected by the PSD as long as the data laser beam is on the groove wall.

A conventional stylus, due to mass and inertia, can not trace highly modulated groove walls properly. A stylus is bounced around by the walls and only plays modulation peaks, while a laser beam, lacking mass and inertia, plays the exact information in the groove with no coloring or shaping of the audio signal.

3.2 Lateral Tracking System

The lateral tracking system keeps the audio detection laser beams (data beams) at the proper location on the groove wall. Positioning of the data beam is critical. It must ride high enough on the wall to stay away from the region near the bottom of the groove damaged by a mechanical stylus. It must also allow the reflected beam to get back to the PSD without being truncated by the opposite groove wall. The beam rides the top part of the groove wall while staying away from the land-groove interface that is frequently distorted by horns, pits, and scratches.

Our laser turntable has both a coarse tracking system and a fine tracking system. Both tracking systems consist of optics and servos, with the servos capable of responding to different frequencies and levels of position change. Motions up to about 10Hz, such as those caused by record runout and the inward groove spiral, are tracked by the coarse system. The optics box rides on a ball bearing slide to cover the four inches of travel required to play the entire record. This lateral carriage is driven by a micro-stepping motor through a rack and pinion gear mechanism.

The fine tracking system consists of two independent, identical, symmetric sets of optics for each of the two channels. Each set of optics has two laser beams hitting the wall, a tracking beam and a data beam (described above). Independent scanner mirrors direct each beam pair to track the groove wall. The tracking beam is directed to ride on the land-groove interface with half the beam hitting the land above the groove, and the other half hitting the groove wall and reflecting back to the data PSD. For all tracking trajectories and beam movements the data beam has a fixed relationship to the tracking beam. Approximate beam geometry is provided in figure 6. The two beams are aligned intrack so that data and tracking signals do not have any relative phase errors. The fine tracking system has a total range of about 500 μ m.

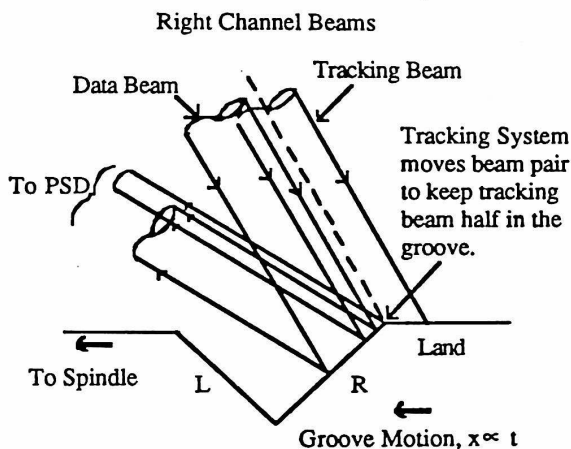


Figure 6: Data and Tracking Beam Geometry (Right Channel)

Requirements for tracking spot size are somewhat different from those for the data spot. Intrack, the tracking spot must be small enough to detect wall displacements of all frequencies and motions that need to be tracked, and large enough to integrate over as much of the wall as possible. Crosstrack, the tracking spot needs to be as large as possible to provide adequate tracking range, while small enough to fit into the groove and not spill over into adjacent grooves. For simplicity, tracking spot geometry is identical to data spot geometry.

One lens, with the two beams incident on the lens non-parallel by 0.026 degrees, produce focussed data and tracking spot centers approximately 10 μ m apart on the groove wall. For all practical purposes the data and tracking beams can be considered to be parallel and coincident in all locations except the small region at the groove wall. Both beams hit the data PSD in nearly identical locations.

Data and tracking beams are generated by separate laser diodes and collected into collimated beams by collimating lenses. The two beams are then sent into orthogonal faces of a beam splitter cube; half of each beam emerges from the other two orthogonal faces to form the left and right channel beam sets. Each set of beams consists of a data and a tracking beam that reflects off an independent galvanometer scanning mirror and then down through the focussing lens onto the groove wall. The focussed spots are moved crosstrack linearly with the scanning mirror deflection angle.

The two lasers are time multiplexed so that the data laser is on when the tracking laser is off and the data laser is off when the tracking laser is on. Outputs of the data PSDs are demultiplexed with high accuracy sample and holds, to separate data and tracking signals. Figure 7 is a block diagram of the electronic circuitry used to process PSD outputs into audio and tracking signals.

The switching rate of the multiplex/demultiplex circuits is 100kHz. Theoretically, this sampled system is capable of reproducing signal frequencies up to 50kHz. Due to practical realizable filters, signal frequencies of up to about 25kHz are accurately reproduced. By contrast, the compact disk is digital (not analog like the optical turntable) and uses a sample rate of 44.1kHz, with the same goal of reproducing 20kHz signal frequencies.

The lateral tracking systems are position following servo systems that always lag behind the trajectory they are following. Beam and groove location are known, but by the time the beams have reached that location, the groove wall has moved again. Our laser turntable measures groove wall velocity as the basic audio signal. This velocity tells the tracking system where the groove is going and how fast.

The velocity signal is processed into a feed forward tracking signal and added to the tracking signal to allow the walls to be tracked with significantly reduced tracking lag and error. This lateral tracking system is capable of tracking the groove wall at rates up to 2kHz with 2.5 μ m accuracy.

3.3 Vertical tracking system

The height tracking system is a low bandwidth servo system designed to move a subset of the optics vertically to track out record warps and thickness variations. The height of the optics head above the record is

sensed with an optical system that is independent of the lateral tracking and audio extraction subsystems.

The height sensor determines the fly height of the optical unit above the record at all times. Figure 8 shows the basic concept of this sensor system. The system sends a laser beam, referred to as the height sensor light beam, onto the land between the grooves. This beam is reflected through imaging lenses to hit a PSD in the image plane of the record. These beams are in the intrack plane containing the tangential velocity vector. As the record drops, the beam position on the PSD is

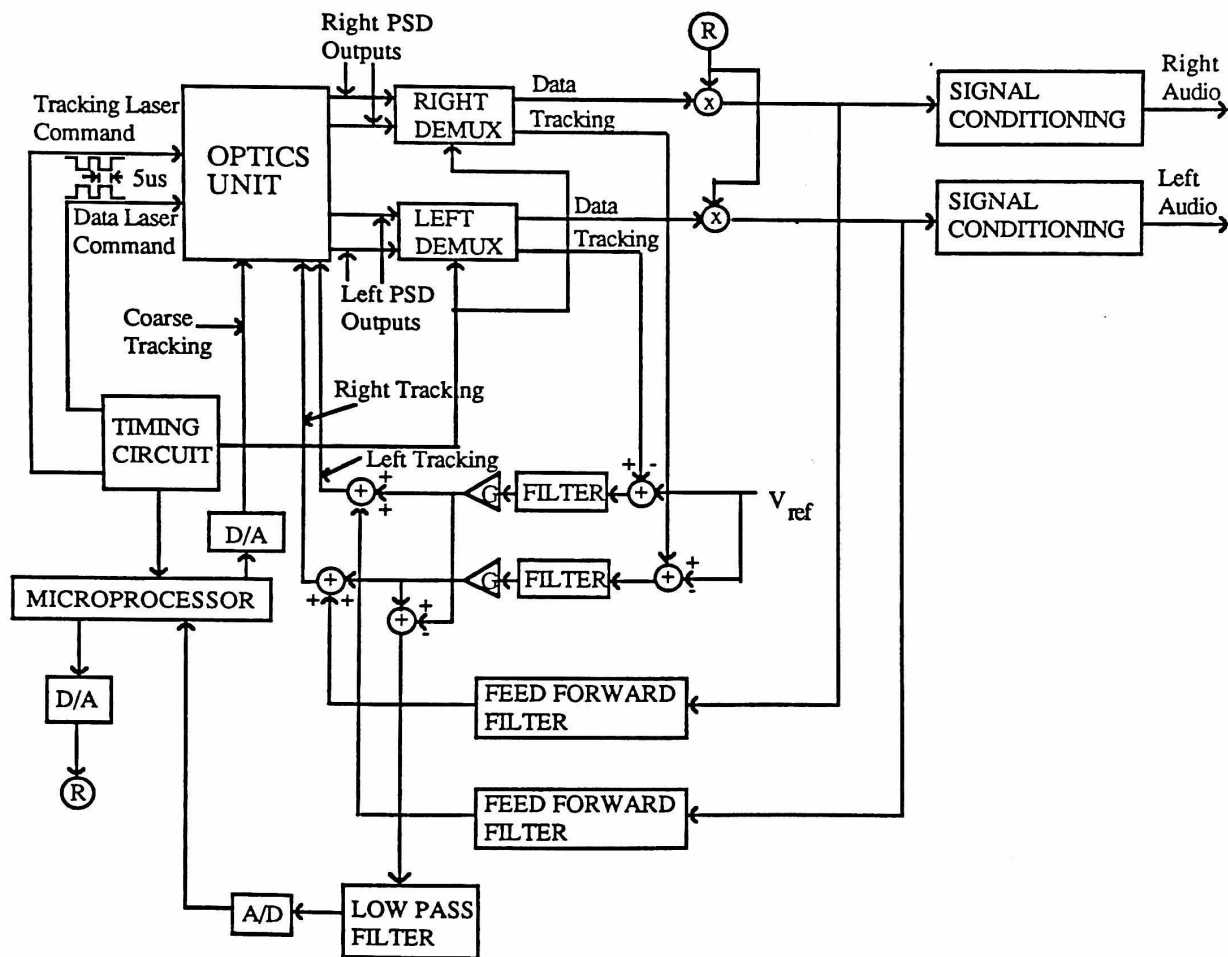


Figure 7: Tracking System Block Diagram

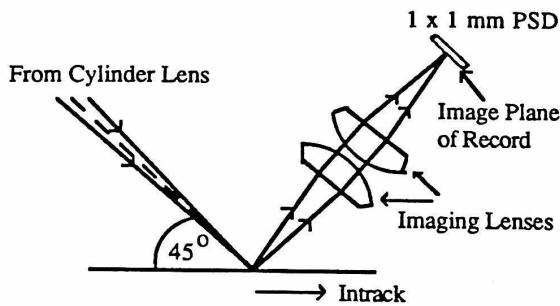


Figure 8: Height Tracking System

affected only by the vertical displacement of the record, not by the angle changes and tilts of the record. The height servo system adjusts the optics height above the record to keep the reflected beam centered on the PSD.

A cylinder lens focuses the height sensor light beam forming a stripe, or line of light, on the record that must be much narrower intrack than the physical wavelength of any signal to which the height sensor actuator would respond. Crosstrack, the stripe must be as long as possible to average over as much area as possible while being short enough to provide height information from the read point and not some distance away from the read point. The read point is the location on the record that the system is playing at any given time. After some experimentation, we settled on dimensions of .05mm intrack by 1mm crosstrack as an effective compromise.

The vertical servo keeps the reflected beam centered on the height PSD and tracks out height errors. The height tracking system moves the height cylinder lens, a height beam directing mirror, the height imaging lenses, the height sensor PSD, the two data focussing lenses, two data beam directing mirrors, and the two data PSDs, vertically. These optics are mounted on a carriage with ball bearings that roll on polished rods. This system is moved by a pair of voice coil motors. The height carriage has a range of about 9mm and is secured in the optics box with a solenoid when it is not playing a record. The accuracy of the height tracking system is $2.5\mu\text{m}$ for warp frequencies below 5Hz (once-around warp components have a warp frequency of 0.55Hz).

3.4 Optical Configuration

Figure 9 shows the optical system configuration. Darker shaded components are mounted in an optics box that is fixed on the lateral drive carriage. This box is roughly 125 x 125 x 38 mm. The lightly shaded components are mounted to the vertical carriage that is roughly 60 x 35 x 35 mm and weighs about 120 grams.

As described in the lateral tracking section, the system has two lasers (data and tracking), immediately followed by collimating lenses to produce a pair of collimated laser beams. The cross-section of the collimated beam is roughly 2.2mm x 6.0mm. A beam splitter divides the tracking beam into two beams. About 10% of the beam transmits through the splitter to form the height sensor beam; the other 90% of the beam is reflected off the splitter to form the tracking beam. The height sensor beam is reflected off two mirrors. It emerges vertically from the fixed optics box to hit the cylinder lens on the vertical carriage. As the vertical carriage moves, the height beam does not move around on the cylinder lens. Below the cylinder lens is a mirror mounted at 67.5 degrees from the record to reflect the converging height beam onto the record at an angle of 45 degrees with respect to the horizontal plane of the record. The height beam reflected off the land, is passed through a unity magnification, low F# imaging lens system, and then hits the height sensor PSD.

The tracking beam reflected off the height beam splitter is sent into a beam merging (splitter) cube. Half the tracking beam is transmitted through the cube forming the left channel tracking beam and the other half is reflected out of the cube to form the right channel tracking beam. The data laser beam hits the other surface of the cube splitter. Half the data beam is reflected out of the cube splitter to form the left channel data beam and is merged with the left channel tracking beam. The other half of the data beam is transmitted through the cube splitter to form the right channel data beam and is merged with the right channel tracking beam.

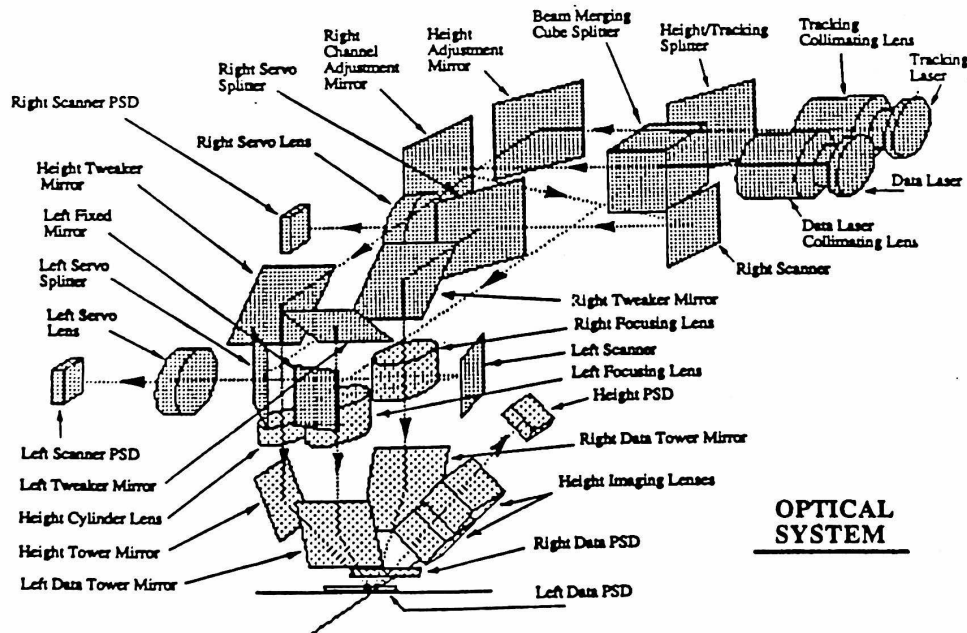
The left channel beams reflect off a fixed mirror to hit the left scanning mirror at about 15 degrees from the mirror normal vector. The scanner deflects the beams vertically to move the focussed spot in the crosstrack dimension.

Beams reflected off the scanner mirror hit the left servo beam splitter. About 10% of the beams are transmitted through the left servosplitter, focussed by the left servo lens and detected by the left scanner PSD. This PSD position output is proportional to the deflection angle of the scanner and is used to control the scanner in an inner servo loop. The other 90% of the beams are reflected off the left servo splitter, then reflected off a mirror to emerge vertically out of the optics box by the left tweaker mirror. Left channel beams hit the left focussing lens on the vertical carriage. These converging beams are reflected off a 74 degree mirror below the focussing lens to direct the focussing beams into the groove at an angle of approximately 58 degrees above the record's horizontal plane. Beams are reflected back at approximately a 32 degree angle to the left data PSD.

Right channel beams emerging from the cube splitter are reflected off the right channel adjustment mirror into the right channel scanner mirror. Scanner to data PSD optics and optical path are identical to the left channel optical system.

4. LASER TURNTABLE FUNCTIONS

For record rotation, the laser turntable uses a belt drive turntable system. Most high quality turntable spindle assemblies use a polished spindle rotating in an oil impregnated, or more exotic, bushing. The bushing system is a good compromise between wow and flutter (rotation smoothness) and rumble (non-rotational motions of the spindle). A ball bearing spindle gives significantly better wow, flutter, and wear characteristics, however, it has significantly higher rumble. Since the laser turntable's audio detection system is not sensitive to rumble, we use a ball bearing spindle to create a turntable system with superior wow, flutter, and rumble specs. Our drive motor is the same 400 pole stepping motor used for the lateral carriage drive. Both stepper motors are driven by a micro-stepping circuit that micro-steps each of the 400 steps 256 times. This results in $360/(400 * 256) = .0035$ degree/micro-step motor resolution and an incredibly controlled and smooth-running motor. The motor is connected to a high-



**OPTICAL
SYSTEM**

Figure 9: Optical System

inertia platter through a custom belt, forming a 1Hz mechanical filter to further smooth platter rotation.

The platter consists of a high-inertia drive hub attached to the bearing spindle, and a light weight platter that rests on top of the hub. A spindle positions the record on the light weight top platter that is covered by a conductive, protective, vibration-absorptive mat. Access to the platter is through a front loading sliding drawer, controlled by front panel pushbuttons. Pressing the "open" button causes the drawer to slide out. The record is then placed on the platter and the "play" button is pressed to close the drawer. The platter then drops precisely onto the drive hub.

A microprocessor controls most turntable functions, including the system setup and play sequence, laser power, lateral carriage, turntable rotation, front panel, output volume level, cueing, and control of error conditions.

After a record is loaded, the vertical carriage lowers toward the record and the height servo closes to force the vertical carriage to maintain a constant distance above the record. Next, the lateral carriage moves from the inner to the outer record radius. While it is moving, a data PSD sum signal is monitored to detect the location of each groove as it goes by. Groove locations are stored in memory and boundaries between cuts are calculated and displayed on the front panel. At the same time, the microprocessor monitors the PSD sum peak level to adjust the laser intensities to the proper level for the record's reflectivity. When the lateral carriage is at the beginning of the record, the platter is brought up to speed, the lateral tracking is locked on the record groove, and output volume level is brought up to line level.

The microprocessor controls platter speed measuring the rotation period of the platter the first time the turntable back panel switch is turned on and correcting it to within a microsecond or so. Platter rotation rate, displayed on the front panel, can be controlled in 0.1 RPM increments from 30 to 50 RPM with a default value of exactly 33 1/3 RPM. From each groove radius and the lateral carriage current radius, various play time values are calculated and displayed on the front panel. Shown on the front panel display are the elapsed, remaining and total time for the cut

being played, as well as for the entire side of the record.

The microprocessor looks for and handles many error conditions. Record errors it can detect include: 1) no record present, 2) extreme record warp, 3) bad vinyl reflectivity (colored records) and 4) skips (or rather, stucks). The microprocessor stores the lateral carriage tracking position as the record rotates in roughly 2 degree azimuth increments. If the record is badly scratched and the optics are skipping to play the same groove over and over, the microprocessor detects that the lateral carriage is at the same radius that it was on during the previous revolution and forces the system to play the next groove. Stucks are caught and corrected within about 20msec. The microprocessor also controls and reports various system errors such as blown or missing fuses, and if the lateral carriage transit screw is engaged while the system is trying to play a record.

5 DISCUSSION

Our laser turntable is a complete system that plays a conventional vinyl record using laser beams and optical sensors instead of a stylus and phono cartridge. The most challenging part of this project has been to understand, measure and bound the mechanical and optical parameters of records; then to design a system to play them. Testing revealed that too many recent records have modulation levels exceeding the system's capture range. As many records as possible were exhaustively characterized and the system redesigned to play these records.

This paper is a simplified overview of the technical concepts behind the laser turntable. Future technical papers will detail the various optical, electrical, signal processing, and mechanical designs in the turntable. These will include record characterization, audio distortion analysis and correction, tick and pop removal with the laser turntable, servo controlled tracking of records, innovative optical scanner designs, and new optical techniques to measure mechanical motions and resonances.

6 ACKNOWLEDGEMENTS

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He has been employed since 1977 as a systems engineer in the fields of servo design and analog and digital electronics and signal processing. He has been working on the laser turntable since January 1984 and is currently a senior engineer at Finial Technology.

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